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Sanderson, E. D.- Strawberry root louse; Destructive pea louse. (1900)

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DELAWARE COLLEGE

AGRICULTURAL

Experiment Station

BULLETIN No. XLIX.

DECEMBER, 1900.

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I.—THE STRAWBERRY ROOT LOUSE.

II.—THE DESTRUCTIVE PEA LOUSE IN DELAWARE.

By E. Dwight Sanderson.

NEWARK, DELAWARE.

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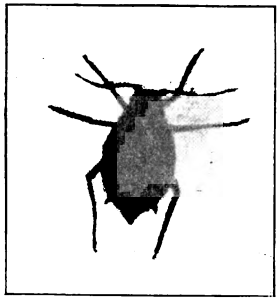
THE STRAWBERRY ROOT LOUSE.

(*Aphis forbesi Weed*).

E. DWIGHT SANDERSON.



Introductory. As the Strawberry Root Louse feeds most of the season upon the roots, plants killed by it here and there do not readily attract the attention of the grower.

Like the San Jose Scale and many other insect pests the Strawberry Root-louse has become generally distributed, and is doing a deal of damage, largely because growers either do not know that such a pest exists or fail to recognize it. Thus one of the most important means for preventing the further spread of this pest and injury by it, consists in the growers being able to recognize it and being watchful for its appearance in their beds. It is for the purpose of acquainting those unfamiliar with the Strawberry Root-louse with its appearance, habits, and injuries, and for suggesting means whereby injury by it may be prevented that this Bulletin is issued.

I. THE INJURY.

1. INDICATIONS OF INJURY BY THE PEST.

Whenever numerous bare spots are found in a strawberry bed, and the remaining plants are more or less unhealthy, failing to mature fruit properly, the owner will do well to examine it for the root louse. If the bed be infested, openings of ants' nests will usually be found very numerous and large numbers of small brown ants will be seen among the plants. Upon pulling up an infested plant many of the roots will be covered with clusters of the little black plant lice.

2. THE INSECT DESCRIBED.

The root lice, or aphids, found on the roots during summer and early fall are very small insects only about one-twentieth of an inch long. They are of a deep bluish-black color, and somewhat pear-shaped, tapering toward the head. When examined under a microscope the three segments back of the head are seen each to bear a pair of jointed legs; a pair of jointed antennae or feelers project from the head, and on either side of the body a short distance in front of the short pointed tail, is a small cylindrical tube, known as a honey tube (Fig. 3). Projecting from the under side of the head and bent on the breast between the legs is a jointed tube, pointed at the tip. Within this tube or beak are four very slender, hair-like bristles, and projecting from the point of the beak are several short bristles. These are shown greatly enlarged in Fig. 1.

3. HOW THE INJURY IS DONE.

In feeding, the insect rests the tip of this tube upon the surface of the root or leaf, and within it the long bristles work up and down

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lacerating the tissue of the root like small lances. The juices of the root or leaf thus set free are sucked up through the beak into the mouth proper. It is evident that the injury which one of these small insects could thus do would be inappreciable; when, however, they become so numerous as to entirely cover the surface of the roots, they soon suck out the juices of the plant to such an extent that it withers and dies or is unable to mature fruit. Rarely is a bed seriously injured during its first year, though often injury is noticeable in the fall. The second season the lice commence to feed early in April, and though only four broods mature before the berries ripen, beds which promised a good yield often mature but a small fraction of a crop. Thus from a four acre bed which promised a crop of about 10,000 quarts of berries in 1898 scarcely 3000 quarts were secured.

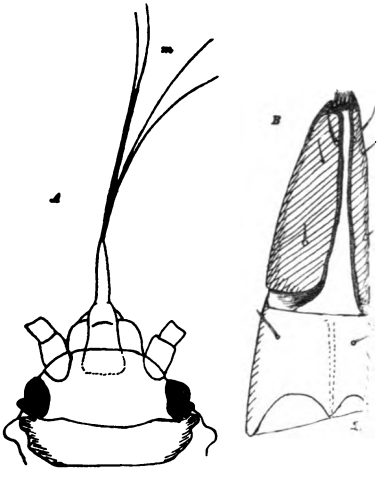

FIG. 1.—A, Head of Strawberry Root-louse, with the beak removed to show setæ (m); B, tip of beak, showing bristles—greatly enlarged. (Original).

4. EXTENT OF INJURY.

Injury done by this pest has been observed by members of the station near Smyrna, Dover, Camden, Felton, Seaford and Bridgeville, where it is believed the injury has been most severe, and also at Newark and other points. Many large and valuable strawberry beds have been badly injured by the root louse in the above localities, sometimes so seriously as to necessitate their abandonment. In several cases the pest has subsequently disappeared from the injured beds, though found in the immediate neighborhood. Very often a bed will be badly injured one year but hardly any lice will be found the next. These cases are the exception and injury is usually more likely to increase than to diminish. Injury seems to be worse on light sandy soil, though beds on heavy land often suffer. The exact amount or extent of the injury in Delaware is difficult to ascertain, as much damage has been done and is being done, where the cause is unrecognized, and has therefore not been called to our attention. Many instances of this kind come to our attention and careful observers familiar with the insect assure us that it occurs in many places where the growers do not recognize it.

5. HISTORY AND DISTRIBUTION OF THE PEST.

The Strawberry Root-louse was first observed in southern Illinois in 1884, but has not done much damage in that State since then. In 1889 it became injurious in Ohio, and was there described and named *Aphis forbesi* in honor of Dr. S. A. Forbes by Dr. C. M. Weed. It is now generally distributed throughout Ohio, where it does more or less injury.

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The pest was first noted in the East in Maryland and Delaware in 1893. Since then it has been the most serious insect pest with which Delaware strawberry growers have had to contend.

In 1896, strawberries were first reported injured by this insect in southern New Jersey, and within the last two years it has spread to near Henderson, Ky. The insect doubtless occurs elsewhere, but has never been recognized.

FOOD.

So far as observed the cultivated strawberry is the only food plant of this species. It is entirely different from the other common root lice infesting corn and various weeds, and also those found on melon and canteloupe vines. It has not been found on any weed or even on wild strawberry plants near infested beds.

II. LIFE HISTORY.

The Eggs (Fig. 2). During the winter the small, shiny black aphis

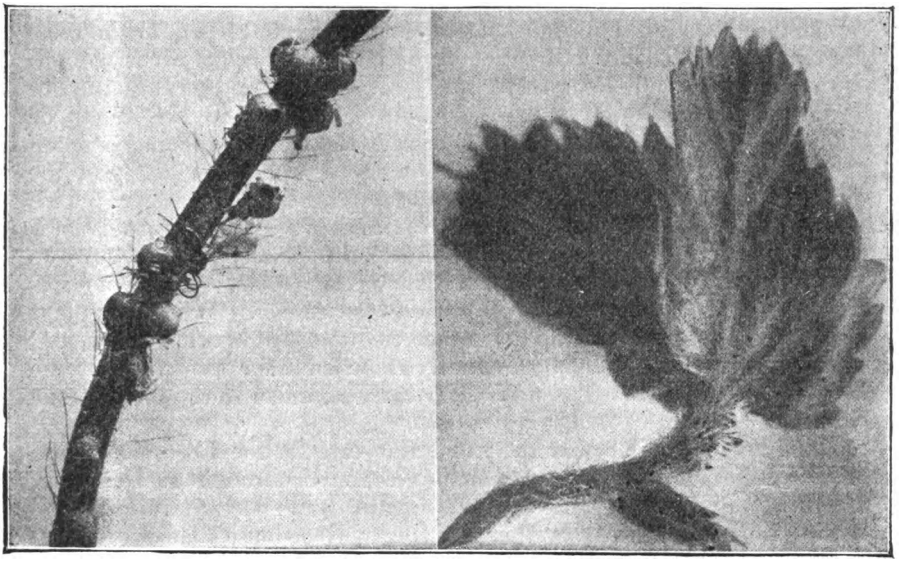

FIG. 2.—Strawberry Root-louse. At the left are inflated parasitized lice, showing holes through which parasites have emerged, and parasitic fly in centre; at the right, a strawberry leaf showing winter eggs. (From photo by the author.)

eggs may be found thickly clustered upon the stems and along the ribs of the green leaves. They are mere specks, about one-thirty-fifth ($\frac{1}{35}$) of an inch long, and are oval in shape. In early winter as many as 65 have been found on the stem and leaflets of one leaf, but many of these fall off and are destroyed before spring.

2. The First Brood. These eggs hatch during the latter part of March or the first ten days of April, the exact time depending upon the season. The young lice first feed upon the leaves bearing the eggs, but soon find their way down among the tender young leaves of the crown.

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This brood of aphids become full grown in about twelve to fifteen days after they emerge from the eggs. These adults, called "stem mothers," now commence to give birth to young aphids, probably bearing fifteen to twenty within a few days. It should be noted that in this and in the subsequent summer broods the adults are all females, males appearing only in the fall; also that these females bear live young instead of eggs, as do the fall brood and almost all other insects, on account of which they are termed *viviparous* (bearing live young) females.

3. The Second Brood. The young born by the stem mothers develop and reproduce in the same manner and in about the same time as the first brood.

RELATION OF ANTS (*Lasius alienus*).

Until the last week in April, but few ants are seen in an infested bed. About this time, however, they are quite numerous, busily carrying the young aphids from the leaves down to the roots of the plants, where are colonies of a dozen or so, rarely more than one colony upon a plant. These colonies consist entirely of young, being unaccompanied by mature females, showing that they had all been carried to the roots by the ants. The ants will be found more active in spots where the soil is dry and sandy. The ants are solely responsible for carrying the lice to the roots as up to the time of the ants' appearance no lice are to be found on the roots. By the middle of May the work of the ants is much more evident. At that time by plunging a trowel under many of the plants, a hollow space may be felt directly beneath the crown. This space usually consists of an ants' nest, containing eggs and larvæ. Radiating from these nests, or irregularly under other plants, the ants' burrows may be found going in all directions among the roots. The ants continue to care for the aphids throughout the season. When one plant becomes overcrowded the aphids are carried to a neighboring plant, and in this way the ants are almost entirely responsible for the spread of the aphids throughout a bed as well as for carrying them to the roots of the plants.

In a very similar way the same ants care for the Corn Root-louse (*Aphis maidi-radicis* Forbes) which is common throughout Delaware. For this reason strawberries planted on corn land—already full of ants' nests—are more injured by the Strawberry Root-louse than when they follow sweet potatoes. The same is true when berries follow for melons are commonly infested with Melon Louse (*Aphis gossypii* Glover), and the attendant ants. Indeed, in a strawberry bed part of which has previously been in corn or melons and the rest in sweet potatoes or some other crop not attacked by aphids, the former part is always much more badly infested by the root lice.

4. The Third Brood. The early stages of the third brood of lice seem to be no different from those of former broods, but when full grown they have two pairs of wings. These winged females are first common about the middle of May, and occur for three or four weeks later. They are quite different from all the other broods which are entirely wingless. Their bodies are somewhat smaller than the wingless forms. They

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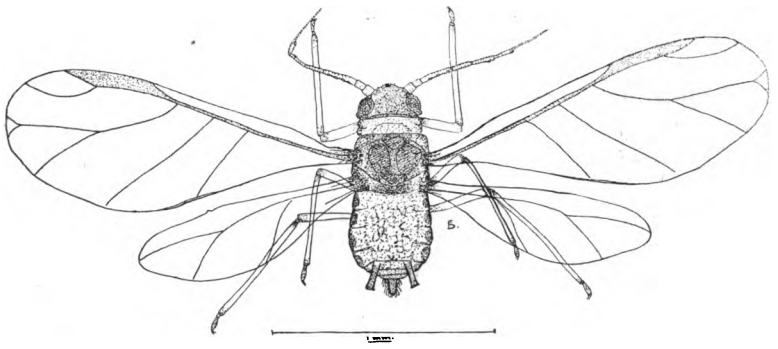

FIG. 3.—Winged Strawberry Root-louse (*Aphis forbesi* Weed), enlarged. (Original.)

appear to be entirely shiny black, though the abdomen is really a deep green. The wing expanse measures about one-sixth of an inch, slightly over three times the length of the body. The winged females reproduce in the same manner as the previous broods, giving birth to live young. It seems that they are also carried to the roots by the ants, as they are but rarely found on the leaves or stems, most of them depositing young on the roots. Where they reproduce on the stems, the roots of such plants are usually already overcrowded with aphids. These winged females probably are not spread by the wind for any considerable distance except from an infested bed which has become very greatly overcrowded. Such beds are usually so badly injured before this occurs that they are worthless and are ploughed up. An old strawberry bed adjoining a much larger and younger one which was well infested with root lice was not injured at all and very few lice could be found in it.

5. Summer Broods. The lice go on reproducing, one brood following another from ten to fifteen days apart during the summer and fall. Part of the fourth brood early in June are winged, and the remainder wingless, as are all subsequent broods. The viviparous females and young are common on the roots until about November 1 in Delaware, but doubtless during an open winter or further south they might continue to reproduce through the winter. Specimens were found on strawberry roots on January 6, which were frozen solid, but revived with warmth and lived for some little time.

6. The True Sexes. Late in October and during November the offspring of a brood of viviparous females develop into the true females and males, which pair and reproduce by means of eggs. These females, called *oviparous* (egg-bearing), are very similar to the summer broods in general appearance, though of a green color, often having a yellowish or reddish shade in the middle of the abdomen, caused by the yellow eggs showing through the transparent body wall. The males are much smaller than the females and hardly to be distinguished from the third stage of the females. The females greatly outnumber the males, the proportion being somewhere near 35 to 1. Each one of the females deposits four eggs upon the leaves or stems as already described. These

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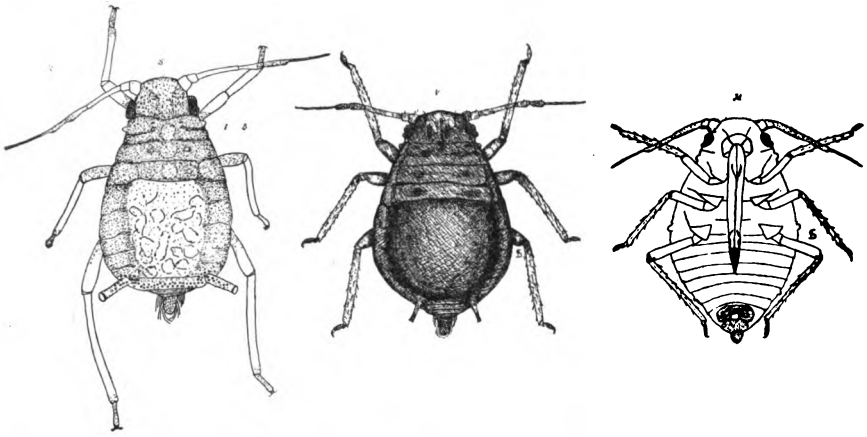

FIG. 4.—Strawberry Root-louse (*Aphis forbesi* Weed). S, "stem mother," or adult female of first spring brood; F, viviparous female of late summer and fall; M, male. Enlarged different proportions. (Original.)

are of a bright orange color when first laid, but within a day or two turn to a bright, glossy black.

7. How the Pest is Spread. From a review of the above life history it may be seen that the pest may be spread in three ways: (1) by the aphids or eggs being introduced upon the plants in setting the beds, (2) by the spread of the winged lice, and (3) by being transported by ants. Undoubtedly the species has been most generally spread by infested plants, either from the nursery or from old beds.

III.—ENEMIES.

The multiplication of this pest receives a considerable check by internal parasites, which develop into small hymenopterous flies. These parasitic flies deposit their eggs on the plant lice and the maggots hatching from them live within the bodies of the lice, usually but one in each. From the effect of this parasitism the aphid soon dies, the skin becoming dry and inflated. From this shell the adult parasitic fly emerges through a large circular hole, as shown in Fig. 2. The appearance of such parasitized aphids is very characteristic, and they should never be destroyed.

Late in May of the present year these parasites became very numerous in one bed, as many as fifty parasitized aphids being found on the stems of three or four leaves. Most of the parasites attack only those aphids above ground, but some species parasitize those on the roots.

Most of the common lady bird beetles and their larvæ (Fig. 6) feed upon the plant lice, but hardly destroy as many as the internal parasites, and do not seem to materially reduce the numbers of the aphids.

IV. METHODS OF COMBATING THE PEST.

A. PREVENTIVE.

For the prevention of injury by this pest *clean plants must be planted*

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upon clean land. Securing these requirements sometimes involves several factors.

1. CLEANING LAND.

Rotation. It is evident that land infested with aphids should not be immediately replanted with berries, for through the care of the ants, a few eggs or viviparous females are very apt to survive either in ants' nests or upon stray plants growing around the border of the field. If it is desired to replant berries after a single year's rotation the land should be put in several crops which require constant cultivation.

As before stated, corn and melons are commonly infested with aphids which are attended by ants, and these crops should therefore never be followed by strawberries, where there is any possibility of the root-louse.

2. CLEAN PLANTS.

As the aphids and their eggs are readily transported on young plants it is of the utmost importance that the plants be secured from sources known to be free from the pest, or, if any doubt exists on this point, that they be thoroughly disinfected.

NURSERIES. Before purchasing new plants the grower should satisfy himself that the nursery—including under this head all parties selling strawberries plants—is free from the pest. For this, the statement of the nurseryman is not sufficient to guarantee freedom from the pest, as but few nurserymen would recognize it unless their beds were badly injured. The certificate of a competent entomologist, stating them to be free from insect pests, should accompany each purchase of plants, and no certificate should be granted nurserymen for plants in an infested bed, though a certificate might be properly given for plants found free from aphis, grown at some distance from those infested.

Where it is desirable to secure varieties from an infested nursery, the purchaser should insist that they be properly disinfected or perhaps better disinfect them himself.

Indeed, it would be to the interest of both the nurseryman and his customer, for him to disinfect all plants previous to shipment, as many now do trees for the San Jose Scale and other insects. This would be but a slight expense, which the purchaser would willingly pay could he be guaranteed clean plants, and would do much to establish confidence in the nursery.

DISINFECTION OF PLANTS. All methods of disinfection must be applied after the aphis eggs have hatched (April 7 this year), as none of them have been found to kill the eggs. Inasmuch as the weather conditions upon which depends the time of planting also determine the time of hatching of the eggs, but little inconvenience will usually be experienced by waiting for all the eggs to hatch. The plants will need to be carefully gone over and the eggs examined with a magnifying glass to see that they have hatched before disinfecting can safely be commenced.

1. Dipping. In dipping plants they should be thoroughly submerged as a few lice will be found both on the leaves and roots at almost any season of the year.

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Kerosene Emulsion.—Dr. C. M. Weed states that he successfully disinfected plants in Ohio by dipping in dilute kerosene emulsion. This may be made according to the following formula:—

Kerosene, 2 gallons; whale-oil soap (or 1 quart soft soap), 1 to 2 pounds; water 1 gallon. Dissolve the soap in the water by boiling, and add, boiling hot, away from the fire, to the kerosene. Agitate violently for five minutes by pumping the liquid back upon itself with a force pump and direct discharge nozzle throwing a strong stream. The mixture will have increased about one-third in bulk and have become about the consistency of cream. Well made, the emulsion should keep indefinitely, and should be diluted only as wanted for use. Dilute this with ten to fifteen parts of water. The plants should not be left in this emulsion more than two or three minutes and should then be well washed in fresh water.

Tobacco Water. Prof. M. H. Beckwith reported success in disinfecting plants by dipping in a strong tobacco decoction, but his experiments were somewhat inconclusive. Prof. G. H. Powell also made tests of this method from which he concluded that "it is propable that the aphids are killed by the tobacco solution, but that the pest is established by the unhatched eggs that are present on the plants" and unaffected by the dipping.

Though no experiments along this line have been made by the writer, inasmuch as both kerosene emulsion and tobacco decoction are the best known insecticides for aphids, there would seem to be but little doubt that thorough dipping of the plants after the eggs have hatched would entirely disinfect them.

2. Fumigation with Hydrocyanic Acid Gas. Though dipping in an insecticide will undoubtedly kill most of the aphids, fumigation by means of hydrocyanic acid gas is much quicker, less work, and a more certain and complete remedy. It should always be remembered that it is a most poisonous gas and should be used with caution.

A. Apparatus. The only apparatus needed is a fair-sized air-tight box similar to that shown in Fig. 5. This box is 2x2x2½ feet, without a bottom, made of two thicknesses of matched wainscotting with building paper between; the cover closes upon a rabbet the depth of the thickness of the material and lined with felt; a small door about 6x6 inches is placed at the lower corner and similarly fitted so as to close on felt; four or five frames covered with wire netting rest upon the cleats, the lower one being about 3 or 4 inches above the ground and extending to the small door, and the rest of the trays extending clear across the box, being about 5 inches apart. Such a box will hold from 1500 to 2000 loose plants, placing only one layer on a frame, which permits a quick and thorough diffusion of the gas.

The only other apparatus necessary is a coffee cup in which to generate the gas.

B. Strength of Gas and Length of Fumigation. Numerous experiments have been made to determine the effect both upon the aphids and the plants of different strengths of this gas and various lengths of fumigation. Though these experiments are not absolutely conclusive,[1] they seem to warrant the conclusion that in a tight box or room, approximately cubical in shape, gas at the strength of $\frac{3}{10}$ of a gram potassium cyanide per cubic foot of space, fumigated for 10 minutes, or $\frac{3}{10}$ of a gram for 15 or 20 minutes, will kill the aphids without injury to the plants. These strengths may safely be recommended for use.

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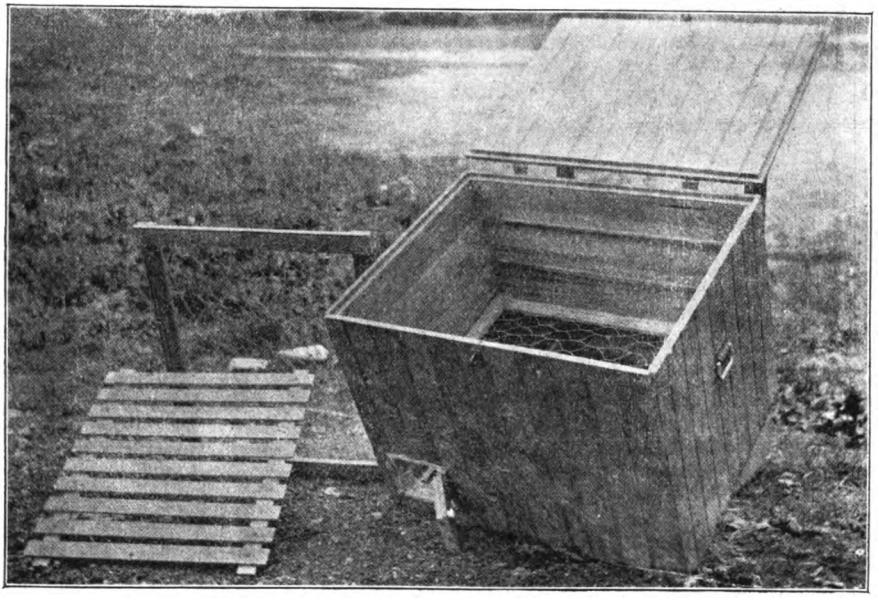

FIG. 5.—Fumigation box. Capacity 10 cubic feet. (From photo by the author.)

C. Procedure. The process of fumigation is essentially the same as that employed in fumigating nursery trees. Earth is firmly packed around the open bottom of the box. The plants, which should be well cleaned of earth, are laid on the trays, the bundles being cut open and thoroughly loosened. The lid of the box is then closed and fastened. A coffee cup or similar vessel is now placed in the lower corner of the box by the door and into it is first dropped a vial containing a proper amount of the cyanide in solution. A vial containing the sulphuric acid is then dropped in and the door quickly closed. Of course the vials are dropped in with the mouths down, and if they be long and narrow the contents will drain out gradually, avoiding a puff of the gas by too rapid generation. The box is kept closed for ten minutes, or as long as desired. Both doors are then thrown open and the trays lifted out so that the plants can be thoroughly aired.

The cyanide solution should be secured from a druggist, put up in homeopathic vials, one dose in each vial. The solution consists of 100 grams 98 per cent. potassium cyanide dissolved in water to make 200 c.c. solution. The amount necessary for each dose is easily computed; multiplying the cubic contents of the box by $\frac{4}{10}$ will give the number of cubic centimeters of the solution to be used (this giving a strength of $\frac{2}{10}$ gram Potassium Cyanide per cubic foot). Use an equal amount of sulphuric acid, which can be readily measured into empty vials. Thus for the box described, 2x2x2½ feet, or 10 cubic feet, 4 c.c. of the solution, or a two-drachm vial half full, and an equal amount of sulphuric acid (best grade commercial, 1.85 sp. gr.) would be used for a strength of $\frac{2}{10}$ gram potassium cyanide per cubic foot, or the same vial three-quarters full for a strength of $\frac{3}{10}$ gram potassium cyanide per cubic foot.

D. CAUTION! Cyanide of potassium is as deadly a poison as is known, and is sure and certain death if taken internally—no antidote being known. Each vial should therefore be plainly labeled in red, with a druggist's poison label as figured:

1 For detailed account of the experiments, see next Annual Report of this Station.

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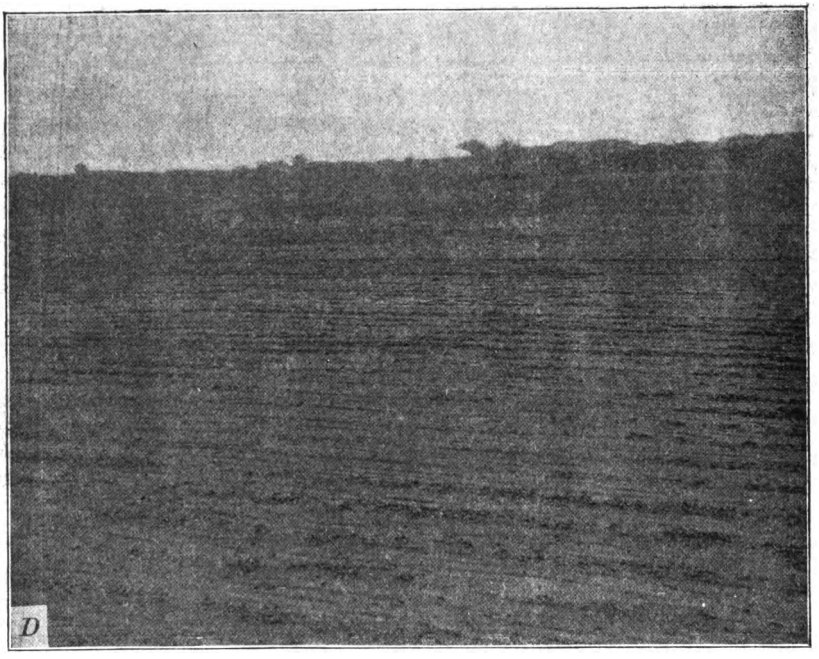

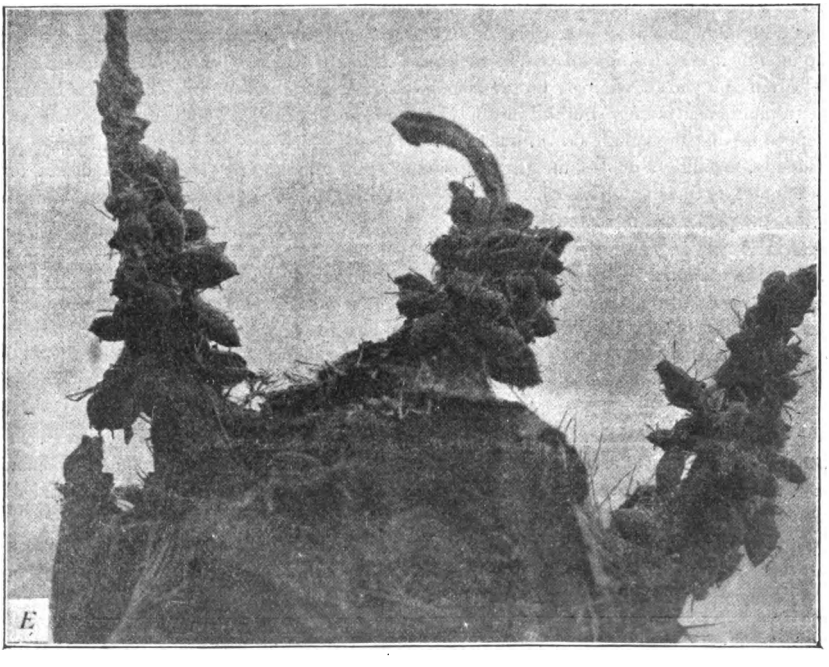

PLATE I.—D, Strawberry field, showing injury by the Strawberry Root-louse (from photo by G. Harold Powell); E, Strawberry Root-lice clustered from small rootlets from crown of plant—greatly enlarged. (From photo by author.)

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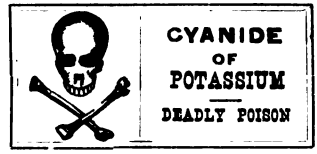

The vials should be locked up and after use should be carefully washed. The residue left after the generation should be washed from the vessel and buried so that it cannot be found by animals. The sulphuric acid should also be labeled and carefully handled, as it will destroy clothing and other things with which it comes in contact.

3. PREVENTION OF INTRODUCTION OF APHIS AFTER PLANTING.

With uninfested plants planted on clean land there exists no chance for injury from the root lice except by the winged form being introduced from neighboring beds. (See page 7.) Thus in many cases it will be necessary to plow under deeply the old infested beds some time before the winged lice appear in order to prevent their spread to the one newly planted.

B. REMEDIAL MEASURES.

1. FERTILIZERS.

Treatment of land with muriate of potash, kainit and tobacco dust at the time of setting and after infested plants were set, was thoroughly tested by Prof. G. H. Powell in 1899 (see last Annual Report of this Station), with wholly negative results. The maximum amount which could be applied with profit and without injury to the plants was tested with each of these substances without effect upon the aphis in any instance.

2. CARBON BISULPHIDE.

For small patches or to preserve a few choice varieties, carbon bisulphide would undoubtedly successfully destroy the pest, though rather an expensive treatment. Prof. Powell found that by injecting two teaspoonfuls of carbon bisulphide six inches (the maximum distance at which effectual) from the plant, by means of a McGowan injector, that the lice on the roots were killed.

Summary of Treatment. As a conclusion from the above, the following procedure seems to be the best method of controlling the strawberry root louse. Plant only absolutely clean plants, requiring a certificate of freedom from insect pests, if purchased; plant only on ground which has not recently been in strawberries; plow under all old infested beds before May 1st, or locate new beds as far from them as possible; if the use of infested plants is unavoidable, disinfect them carefully by dipping or fumigation, and do not plant them on land previously in strawberries, corn, or melons. These measures are all preventive; no successful remedial measures are known.

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THE DESTRUCTIVE PEA LOUSE IN DELAWARE.

(*Nectarophora pisi* Kalt.)[1]

E. DWIGHT SANDERSON.

I. SUMMARY.

The Destructive Pea Louse destroyed 56 per cent. of the Delaware pea crop in 1899 and with dry weather caused a loss of 47 per cent. in 1900. Injury was much worse to peas sown broadcast or in 8 inch drills.

The lice feed upon clover in late fall, winter and spring.

Large numbers of the lice are destroyed bp parasitic and predaceous insects, but more by a fungous disease. This disease is more prevalent in wet springs when the lice are consequently less numerous.

If practicable clover badly infested with lice should be deeply plowed under and rolled to prevent their spread to peas.

Peas planted upon well fertilized land, and frequently cultivated, will sometimes bear a fair crop though attacked by the lice.

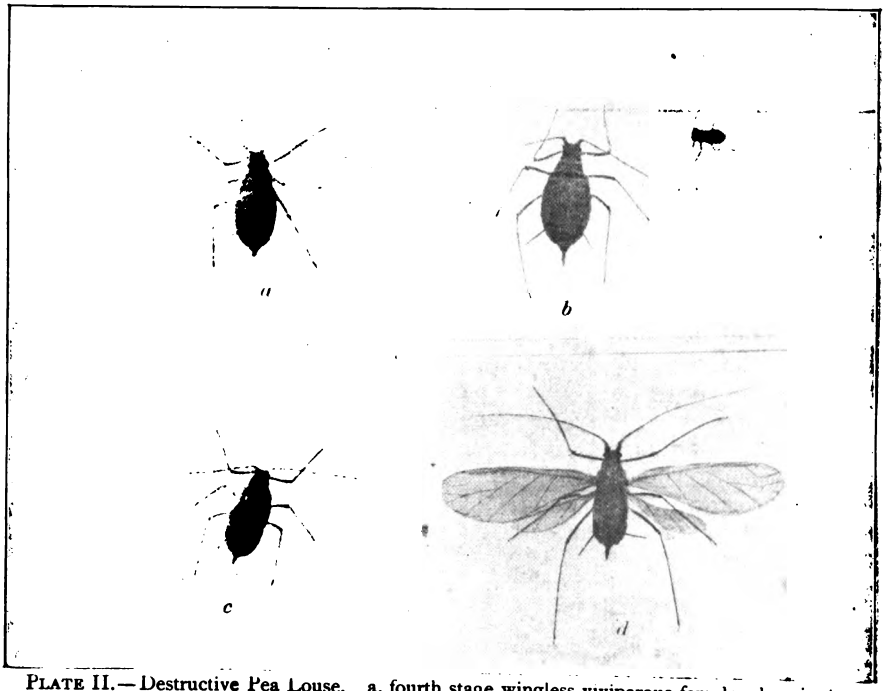

PLATE II.—Destructive Pea Louse. a, fourth stage wingless viviparous female; b, wingless viviparous female and young; c, pupa; d, winged female. (From photo by the author.)

1 *Aphis pisi* Kalt., Curtis.; syn. *A. ulmariæ* Schrank, Tasch., *A. onybrachis* Fonsc., *A. lathyri* Walker, Mosley., *A. viciæ* Curt. (pars ?), *Siphonophora pisi* Koch, Buckton, *S. ulmariæ* Pass., *S. gei* Koch (?), *Nectarophora pisi* Oestlund, *N. destructor* Johnson. A further discussion of the identity of the species will be published shortly.

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Plant only in rows 18 to 30 inches apart.

Do not plant late peas next season.

In warm weather with dry soil, brush the vines with pine branches during mid-day and follow the brushes by a cultivator. Otherwise, brush the lice from the vines into a shallow pan drawn between the rows and partially filled with water and kerosene.

The Destructive Pea Louse needs no introduction to Delaware pea growers. In the spring of 1899 it introduced itself, and during the past two seasons has compelled a most disagreeable acquaintance, by the serious injury it has done to the pea growing industry.

II. THE INJURY.

To secure an accurate estimate of the damage done by the pea lice during the past two seasons statistics have been secured giving the number of bushels of seed sown, and number of cases (2 dozen cans) packed of early and late years 1897 to 1900 inclusive.

NUMBER OF BUSHELS OF PEAS SOWN AND CASES PACKED IN DELAWARE, 1897–1900.

1897 (3 FACTORIES).						1898 (6 FACTORIES).					
No. BUSHELS SOWN.			No. CASES PACKED.			No. CASES PACKED.			No. BUSHELS SOWN.		
Early.	Late.	Total.	Early.	Late.	Total.	Early.	Late.	Total.	Early.	Late.	Total.
1525	975	2500	33,500	23,000	56,500	2926	1700	*6426	68,250	39,602	*153853

1899 (7 FACTORIES).						1900 (10 FACTORIES).					
No. BUSHELS SOWN.			No. CASES PACKED.			No. BUSHELS SOWN.			No. CASES PACKED.		
Early.	Late.	Total.	Early.	Late.	Total.	Early.	Late.	Total.	Early.	Late.	Total.
3665	2160	*7625	54,509	11,512	*92,021	4435	1818	*7053	75,355	13,100	*113455

*Including two factories estimate by the writer.

NUMBER OF CASES (2 DOZEN CANS) OF PEAS PACKED PER BUSHEL OF SEED SOWN.

1897.			1898.			1899.			1900.		
Early.	Late.	Av.	Early.	Late.	Av.	Early.	Late.	Av.	Early.	Late.	Av.
21.96	23.5	22.73	23.29	23.23	23.26	14.87	5.28	10.07	17.0	7.20	12.10

The above figures speak for themselves; a loss of half the whole pea crop and two-thirds to four-fifths of the late crop, for two years, falling almost entirely upon the growers, is a most serious menace to the pea-canning industry. It will be seen from these figures that the

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crop of 1900 was but slightly better than that of 1899. This was not entirely due to the work of the Pea Louse, however, as a dry spell in May injured the medium late peas very considerably, so that very often they yielded no more than the late varieties, though not seriously injured by aphids.

The lice commenced to appear on peas this season about May 1, though rarely present in appreciable numbers until ten days later.

Injury to peas was general throughout the state, but was most severely felt in the southern part, where peas are largely grown for the canneries, especially around Bridgeville, Seaford, Milford, and Harrington. Most of the observations were made at these points.

Almost without exception the early Alaska peas were but slightly if at all infested and injury to them was rare. The medium late varieties, Blue Beauty, French Canner, and Admiral, blossoming about the third week in May in southern Delaware, were more or less injured by the lice but were worse damaged by dry weather. But by the time late varieties, Horsford's Market Garden and Advancer came into blossom, about June 1, the lice had become so numerous that they prevented the formation of pods or stunted their growth so as to render them largely worthless. As a result, rarely was half a crop of the late varieties secured and more generally they were a complete loss.

Peas Sown Broadcast or in Drills.—The above statements refer entirely to peas planted in rows 20 to 30 inches apart and cultivated. Peas drilled in rows 8 inches apart or sown broadcast were much worse injured, even the early varieties sometimes being an entire loss. At Harrington one field was planted broadcast with 40 bushels of Alaska and Admiral, from which the owner cut about one ton, which was so worthless that the rest was cut for feed.

III. PAST HISTORY OF THE PEST.

In America widespread injury by this insect has been done only during the past two seasons. Last year its ravages extended along the Atlantic Coast from North Carolina to New Brunswick and Nova Scotia, and in Ontario and Ohio. This year in addition to these localities injury was reported from northern Wisconsin.

But this pest is by no means a new one. In Europe, where it is called the "Green Dolphin" it has been known as one of the worst pests of peas and vetches for over a century. Through the kindness of Mr. G. B. Buckton, F. R. S., Haslemere, Eng., we have secured specimens which when compared with specimens of the Destructive Pea Louse prove to be of the same species. Kirby and Spence writing in 1815 give an account of the damage done by this pest which corresponds very closely with our own experience. "Those (aphids) which attack pulse spread so rapidly, and take such entire possession, that the crop is greatly injured, and sometimes destroyed by them. This was the case in 1810, when the produce was not much more than the seed sown; and many farmers turned swine into the pea fields, not thinking them worth harvesting. The damage in this instance was

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caused solely by the aphis, and was universal throughout the kingdom so that a supply for the navy could not be obtained. The earlier peas are sown, the better chance they stand of escaping, at least in part, the effects of this vegetable Phthiriasis." It is also remarked that the pest is worse in dry seasons.

The insect is evidently either native to this country or has been established here for many years. The first record of its occurrence was in Minnesota in 1887 on Shepherds Purse.[1] Since then it has been noted in Nebraska and Illinois on clover, beets, peas, and other plants.

Early in May, 1890, an experimental plot of crimson clover at this station was so badly attacked by what was undoubtedly this species of aphid that for a time it was feared the experiment would prove a failure.

One or two extensive growers of crimson clover inform me that they have seen this pest on crimson clover for at least six or seven years. As no other aphid is known to attack clover in any considerable numbers, there seems to be little doubt but that the same species has been present in Delaware for at least ten years. Mr. F. A. Sirrine writes me that Long Island pea growers state that "they had a similar trouble with their peas eight or ten years ago." In 1887 an aphid very similar to this species, and probably the same, was observed by Dr. L. O. Howard, U. S. Entomologist, on clover at Washington, D. C.

IV. DESCRIPTION OF THE PEST.

Both winged and wingless lice occur together commonly throughout the season.

The winged lice (Pl. II, d.) are from one-eighth to one-seventh of an inch long, with the wings expanding about two-fifths of an inch. Most of the body is of a pea green color, and light yellowish-brown between the wings and on the head. The eyes are red. The legs, antennae or feelers and honey tubes are yellowish tipped with black. The wingless females (Pl. II, b.) are similar to the winged in size and color, but are much broader across the abdomen and the honey tubes somewhat longer.

The mouthparts of the pea louse like those of all other plant lice, are similar to the mouthparts of the Strawberry Root-louse (see page 3). It secures its food by puncturing and sucking up the juices of the plant.

The plant is thus injured in the same manner as the strawberry by the root louse, by the large numbers of lice sucking out the juices and thus causing it to wilt and die, though in this case it is the leaves and stems which are attacked.

V. LIFE HISTORY.

The Pea Louse passes the winter upon clover, preferably crimson clover in Delaware, which is probably due to its being more succulent than red clover.

About May 1st winged females spread to the peas upon which they

1 Thomas mentions it in Illinois in 1879, but his description evidently applies to another species.

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deposit young which develop into wingless viviparous females. These females, as do those of subsequent broods, bear live young, reproducing in the same manner as the Strawberry Root-louse (see page 5). Reproduction goes on very rapidly until the latter part of June. Winged lice develop as often as the food plant becomes overcrowded and it is necessary to spread to other plants to prevent starvation. About twelve days are required for a louse to become full grown. Prof. Johnson has shown that in the spring a female gives birth to from 110 to 120 young.[1]

In the fall as cold weather approaches fewer young are born; only about twenty-five by each female late in October. Thus it is due to this power of extremely rapid reproduction that the aphids multiply so quickly and become so numerous as to do serious injury.

By July 1st the lice had been almost exterminated upon peas by predaceous and parasitic insects and disease, and were not observed during midsummer. In September they became common again, multiplying very rapidly on the few late garden peas then to be found. Late in October the lice spread to clover. The winged female which goes from the peas to clover is much smaller than the summer winged females. The feelers and body between the wings are blackish. This form is known as the fall migratory winged female. About November 1st a few winged male lice appear on peas and clover. They are similar in size and color to the migratory females, though slightly darker, and have three or four small black spots along the sides of the abdomen in front of the honey tubes, and a small, irregular, deep brown dash on either side of each abdominal segment above the lateral spots.

By analogy with the life history of other plant lice, such as the apple plant louse (*Aphis mali*), the appearance of a male would lead one to expect that the young deposited on clover by the migratory females would develop into true females (see page 7), which would lay winter eggs. But as far as observed such is not the case, at least in this latitude. The young born upon clover develop into viviparous females, which go on reproducing until severe cold weather sets in, and probably without interruption in an open winter. Possibly farther north true females may occur and eggs be laid, but in this latitude it is not uncommon for plant lice to reproduce for an indefinite length of time without eggs being produced. Mr. F. A. Sirrine has kindly sent me specimens of a very nearly related aphid (possibly the same) bred from eggs found on red clover in Iowa in the spring of 1893.

Early in the spring the lice commence reproducing upon clover, and if they multiply without any check from insect enemies or disease, they spread to peas as soon as the clover becomes crowded with them, or when approaching maturity it loses its succulence and they find the young peas a more desirable food.

1. FOOD.

Undoubtedly clover is the original food plant of the pest in this

1 Circular No. 7, Md. St. Hort. Dept. (May 12, 1900), also Bull. No. 28, n. s., Div. Ent., U. S. Dept. Ag., p. 56.

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country. In Delaware but few lice have been found upon red clover, a decided preference being shown for the crimson clover, this doubtless being due to its greater succulence. No injury was reported to clover in Delaware this year, though in many cases the crimson clover was well covered with the aphids, but, as noted above, it has been observed in the past, and both red and crimson clover were seriously damaged in Maryland and elsewhere during the past two seasons.

At Washington, D. C., the lice were found feeding upon various vetches during the winter. Alfalfa adjoining infested fields of crimson clover was found entirely free from lice. The lice have also been very injurious to sweet peas, Canada field peas and vetches in Canada.

In Europe this insect has a long list of food plants, including peas, clover, vetches, and many common weeds.

2. SPREAD OF THE PEST.

Undoubtedly the pest is principally spread by the winged viviparous females being carried by the wind. The manner in which they spread from crimson clover to peas was interesting in that they attacked only the late peas. Next to a badly infested field of clover was a large field of peas, early, medium and late; only the medium and late varieties were attacked, the medium but slightly, and hardly an aphid was to be found on the Early Alaska.

VI. ENEMIES OF THE PEA LOUSE.

1. PARASITIC INSECTS.

A few of the parasitic flies whose maggots feed internally upon aphids—similar to those attacking the Strawberry Root-louse (see page 8) were bred from pea lice in the fall of 1899. Parasitized aphids were fairly common on the crimson clover, but none were found upon peas until June 11. Probably about 5 per cent. of the aphids were killed by these parasites, showing that they are of but little value in checking their increase.

2. PREDACEOUS INSECTS.

Syrphus Flies.—Among the most beneficial of the insects predaceous upon the Pea Louse are the larvæ of the syrphus flies. Three species of these flies were numerous, the most common, the American syrphus (*Syrphus americana* Weid.) is shown in Pl. III, D. These syrphus flies deposit a single small, oval, white egg in a colony of plant lice. From this hatches a small maggot which becomes about one-half to five-eighths of an inch long when full grown, of a green or brownish color, and shaped as shown in Pl. III, A. These maggots have no legs nor distinct head. When once a louse is grasped by the maggot's small hook-like mouthparts it is held aloft, the maggot waving its body to and fro in the air, and the juices of its body are quickly sucked out. In this manner a maggot has been observed to eat 25 apple plant lice in as many minutes.

These syrphus flies were not abundant until May 30, though a few occurred earlier. About June 18th the third brood was swarming over

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the field, a half-dozen being seen upon a couple of feet of vines, and making a very audible buzz over the field.

2. Lady Bird Beetles. Several species of the common lady bird beetles and their larvæ were common throughout May, but not until the second week in June did they become abundant. These beetles lay their small, orange-yellow eggs in small clusters. From them hatch active little six-legged larvœ, which have a fancied resemblance to miniature alligators. When full grown these larvæ are about one-half an inch long, blue or black, spotted with bright orange, and with numerous small warts or tubercles bearing black spiny hairs, scattered over the bodies. When full grown the larva attaches itself to a leaf by its tail and sheds its skin, thus transforming into a pupa. The pupa hangs pendant from the leaf, with the head, wings and legs folded close to the body for a week or so, when the adult beetle emerges from it. Though both the larvæ and adults (Fig. 6) of these beetles ate large numbers of the pea lice in June, they were too late to prevent the worst injury.

3. Lace Winged Fly. The larvæ of the Lace-winged Fly are also common in infested fields and consume their share of lice. The adult fly is of a bright pea green color, with the veins of the wings forming a fine lace-like network, and with shining golden eyes, on account of which it is often called "Golden Eyes" (Pl. III, H, I). Its eggs are laid singly, sometimes several on a leaf, and each is placed at the end of a stalk of silk (Pl. III, E). Were it not for this ingenious device, when a young larva hatched it would undoubtedly devour all the other eggs. As it is, older larvæ often eat their younger brothers and sisters. These larvæ are considerably smaller and much more active than those of the lady bird beetles. Projecting from the front of the head are the two long sickle-shaped jaws, which are hollow. With the tips of these a louse is firmly grasped and its juices sucked into the mouth through the hollow mandibles. When full grown the larva spins around it a small globular, glistening, white cocoon of silk, and within this transforms to the pupa (Pl. III, Fig. G), which in due time transforms to the adult fly.

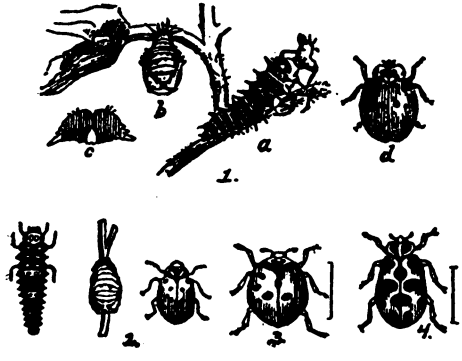

FIG. 6.—Lady-bird Beetles. 1, Thirteen-spotted Lady-bird; a, larva eating plant louse; b, pupa; d, beetle; 2, Convergent Lady-bird (*Hippodamia convergens*); 3, The Nine-spotted Lady-bird (*Coccinella 9-notata*); 4, *Megilla maculata*. (After Riley).

Many other insects feed upon the Pea Louse, but the above have been by far the most important in Delaware. Though they do a great deal to lessen the numbers of the lice, altogether the insect enemies of the Pea Louse appear too late to prevent the bulk of the injury, and as this was true in 1899, it seems impossible to place any dependence upon them.

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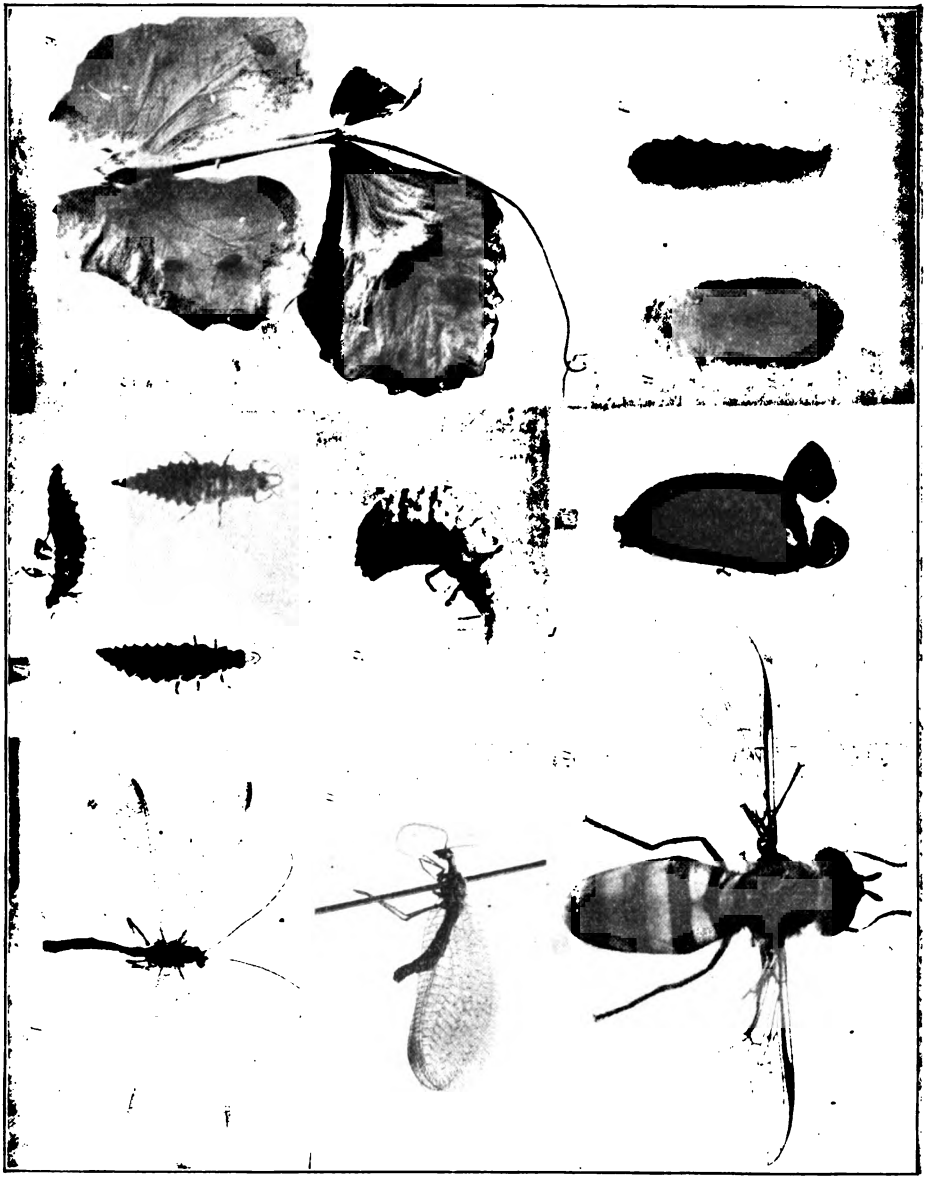

PLATE III.—Insects predaceous upon the Destructive Pea Louse: The American Syrphus Fly (*Syrphus americana* Wied); A, larva; B, puparium; C, puparium after escape of fly; D, adult fly; the Lace Winged Fly (*Chrysopa oculata*); E, white eggs upon stalks, and lice killed by fungous disease; F, larvæ; G, pupa; H, adult fly, side view with wings closed; I, same, wings expanded.—all enlarged. (From photo by author).

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3. FUNGOUS DISEASE.

The most important enemy of the lice is a fungous disease—*Empusa aphidis*. Individuals killed by this fungus were found on clover early in the season, but not until June 11th were diseased lice found in any quantity. After that so rapidly did the disease destroy them that a week later but very few lice were fouud, and almost all were diseased.

In 1890 when clover was injured here early in May, the lice were destroyed by this fungus by May 12th.

VII. CAUSES OF THE OUTBREAK.

The causes which have lead to the most unusual and remarkable outbreak of the Pea Louse during the past two seasons are still shrouded in obscurity. It has seemed quite possible that the severe weather of February, 1899, may have killed off the internal parasites of the pest and thus left it free to increase abnormally; but there are several reasons for doubting the possibility of this theory.

A more probable explanation seems to be along the following lines. The chief natural factor in the control of the pest seems to be the fungous disease *Empusa aphidis*. The growth of this fungus requires slightly warm, wet weather, and is prevented by drought. April, May and June, of 1899, in Delaware, Maryland and New Jersey were altogether the driest for the past ten years, and with local exceptions, this was true throughout the Atlantic Coast, Ohio Valley, and Lake Region. Following this. April and May of 1900 were almost equally dry, though in June the rainfall was much above the normal. In 1899 the fungus did not destroy any considerable number of the lice until about June 18th, and from all accounts their destruction was most largely due to predaceous insects. In 1900 the disease appeared much earlier, destroyed large numbers of the lice, and their disappearance by the 18th of June was mostly due to it. In 1890, the lice were destroyed by this disease at Newark, Del., on clover by May 12th. The rainfall of May, 1890, was above the normal at Newark, and the preceding winter was an unusally mild one, seemingly corroborating the view that a wet spring is favorable to the development of the fungus, which destroys the aphids on the clover and prevents them from becoming numerous enough to spread to peas.

The data concerning this matter are yet too meager to enable us to definitely ascertain the cause of the outbreak, but with the knowledge we now have, the above theories seem the most probable.

VIII. MEANS OF COMBATING THE PEST.

1. PREVENTIVE.

1. Management of Clover.—Inasmuch as the lice spread from clover to the peas, it will be advisable to plant as little clover immediately next to peas as possible. In the spring the lice should be carefully watched on the clover. Should they become over abundant, the management of the clover will depend upon several factors. If it has been planted as a cover crop to be turned under for green manure, it will probably be best to turn it under deeply at once, even though it has not made the desired growth, and thoroughly roll the field. If planted for hay, its treatment will depend upon whether it or the peas are of most value, and whether other fodder, such as cow peas for instance, can be grown to replace it.

2. Culture and Fertility of the Land.—Highly fertilized land in which the moisture is held by frequent cultivation very often enables a crop attacked by insects to mature in spite of them. Peas attacked by

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the Pea Louse, especially the early and medium late varieties, are no exception to this. In 1899 one grower near Milford, whose land is in a high state of fertility from the use of crimson clover and lime for several years, secured $30 an acre from his early and $15 an acre from his late peas, though both were badly attacked by the lice, while neighboring crops hardly paid for the seed. This was undoubtedly entirely due to the fertility of the land and constant cultivation of the land.

3. Planting in Rows.—As noted above peas sown broadcast or planted in eight-inch drills have universally been much more seriously injured by the lice than those planted in rows from 18 to 30 inches apart and cultivated. Furthermore, peas planted broadcast or in drills afford no opportunity for brushing or cultivating. It is, therefore, absolutely necessary that peas be planted in rows as long as there is any chance of the appearance of the pea louse.

4. Late Peas.—As only late peas were seriously injured this year and were much the worst injured in 1899, it would seem worse than useless for the general grower to plant late peas—at least for a year or two. It will undoubtedly be to the best interest of growers not to attempt raising late peas for a year or two, and to the interest of the canners not to encourage them otherwise. It will be well for a few canners to plant such sized plots of late peas as they care to risk the loss of, so as to determine when injury to late peas by the lice lessens, for doubtless sooner or later within a very few seasons the Pea Louse will cease to be generally injurious, and it will then be safe to plant late peas again for a series of years until another outbreak of the pest occurs.

2. REMEDIAL.

1. Spraying.—In an experiment by us in which an acre was sprayed with 25 per cent. kerowater, a very large majority of the lice were killed with no injury to the vine. However, as Prof. Johnson (l. c.) found spraying unsuccessful after a very thorough trial upon 100 acres and using all sorts of insecticides, spraying can hardly be recommended from our present experience with it. Furthermore, both the materials and apparatus for spraying are doubtless too expensive for the average pea grower.

Brushing followed by Cultivator.—Early in the present season Prof. Johnson found that when peas were planted in rows that the lice could be readily knocked from the vines by means of brushing with a pine branch, and that by thus knocking the lice off between two rows and following the brushes with a cultivator, the lice would be destroyed by covering them with earth and their dying from suffocation or from the heat of the soil. "Where the lice are brushed off on the ground in the hot sun, with the thermometer varying from 94 to 96 degrees Fahr., they are actually roasted to death in a few minutes. The temperature of the ground was from 115 to 119 degrees Fahr. The cultivation should not be repeated until the third day, as it requires usually something over forty-eight hours for the destruction of the adult insects covered with earth" (*i. e.*, if the soil is not hot enough to kill them at once). "Peas that will not admit of frequent cultivation should be

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brushed at midday."[1] By the use of this method several parties in Maryland under the direction of Prof. Johnson were able to save large areas of peas. This method was also used with more or less success in Delaware, but it was frequently found that when the soil was moist it would form small clods after cultivation and that lice would then merely crawl out from under them back on to the vines.

3. Brushing into Pans. To meet this difficulty, Prof. Johnson devised an arrangement into which the lice might be brushed and thus caught. This is modeled after the "hopperdozers" used in the west for

FIG. 7.—Showing the structure of pan and use of it with brushes against the Destructive Pea Louse. This field was saved by its use. (After W. G. Johnson, Bull. No. 28, Div. Ent., U. S. Dept. Ag.)

catching grasshoppers, and consists of a long, shallow pan the width of the distance between the rows and five or six inches deep. In the bottom of this is placed a little water, which is covered with kerosene. This pan is drawn between two rows, while a boy on each side brushes the lice into it, where they are soon killed on coming in contact with the kerosene. The pan should be frequently cleaned of lice, so that it will not become filled up and prevent those falling from coming in contact with the kerosene. These pans may be easily and cheaply made from galvanized iron, and are also readily operated at small cost. The "hopperdozers" have been used for many years in the west over thousands of acres with the best of success, and we would recommend a careful trial of this method, which seems to be by far the best means of destroying the Pea Louse.

1 W. G. Johnson, Circular No. 11, Md. St. Hort. Dept. (May 15, 1900,) and Bull. No. 28, n. s., Div. Ent., U. S. Dept. Ag., p. 57. See also Circulars No. 13 and 17 Md. St. Hort. Dept.

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